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ABSTRACT

This paper presents plant food preferences and food consumption rates of captive deer mice (*Peromyscus maniculatus*) and Great Basin pocket mice (*Perognathus parvus*). This information is used to estimate the impact of these species upon a 1 km² shrub-bunchgrass community in Curlew Valley, Utah, where the densities of rodents and plants are known.

The captive rodents preferred seeds of squirreltail grass (*Sitanion hystrix*). They ate only small amounts of halogeton (*Halogeton glomeratus*), little rabbitbrush (*Chrysothamnus viscidiflorus*), tansy mustard (*Descurainia pinnata*), shadscale (*Atriplex confertifolia*) and big sagebrush (*Artemisia tridentata*). Deer mice and pocket mice respectively consumed an average of 7.31 and 8.18 kcal/day of energy contained in plant parts during the experiments.

Deer mice and pocket mice were the most common rodents in the Curlew Valley study area. They removed an estimated 6% or less of dominant plant parts during the summer and fall. The rodents' consumption probably had little effect upon plant biomass or productivity in the study area.

INTRODUCTION

Biologists have conducted many studies on rodent food habits and on plant productivity, but they have done relatively little to relate one to the other. The data available suggest that the influence of rodents upon plant communities may vary widely. It appears that rodents generally consume less than 2% of net primary production (Golley 1960; Odum et al. 1962; Chew and Chew 1970); however, granivorous rodents sometimes may consume nearly 11% of available primary production in desert communities (Chew and Chew 1970; Soholt 1973). Further, because rodents are selective in what they eat, their impact is not uniformly distributed among plant species. For certain plants this impact may be considerable; for instance, Soholt (1973) found that a granivorous rodent in one desert community ate 95% of one plant species' annual seed production. More information is needed on relationships between various kinds of rodents and plant communities before reliable generalizations can be made about the impact of rodents upon plants. This study attempts to contribute to the effort by estimating the impact of two sympatric species, deer mice (*Peromyscus maniculatus*) and Great Basin pocket mice (*Perognathus parvus*), upon some common plant species in an arid lands shrub-bunchgrass community.

METHODS

The investigation included three phases: 1) consumption experiments in which captive deer mice and pocket mice were presented known quantities of common plants; 2) observations of mice feeding on these plant species in outdoor arenas; and 3) integration of the experimental results with available information on vegetation and rodent densities of the Curlew Valley southern shrub Validation Site, Desert Biome Program.

Consumption trials and observation trials were conducted between 1 July and 1 October 1975 at the Green Canyon Ecology Research Station near Logan, Utah. Animals and plants to be used in the experiments were collected biweekly near the Curlew Valley southern shrub Validation Site (approximately 50 km SW of Snowville, Utah) and transported immediately to the research station. Deer mice and pocket mice were live-trapped, sexed and aged. Potted whole plants and plant parts of the following dominant plant species were collected: big sagebrush (*Artemisia tridentata*), shadscale (*Atriplex confertifolia*), little rabbitbrush (*Chrysothamnus viscidiflorus*), squirreltail grass (*Sitanion hystrix*), halogeton (*Halogeton glomeratus*) and tansy mustard (*Descurainia pinnata*).

Four deer mice and 12 pocket mice were used in the consumption trials. In each trial, a single mouse was placed for three days in one of four 76 x 32 x 21-cm outdoor terraria. Each terrarium contained one 300-cm³ can with paper nesting material, one 10-ml syringe containing water and approximately 3 liters of desert soil sifted through a 0.71-mm mesh wire screen. The following plant parts were presented daily between 1600 and 2000: squirreltail grass seeds (4 g); shadscale fruits and leaves (3 g); sagebrush leaves, stem tips and flower parts (2 g); rabbitbrush flower parts (2 g) and halogeton leaves, stem tips and flower parts (2 g). At the end of the first and second days, most of the plant material remaining in a terrarium was removed, weighed and replaced with fresh material. At the end of the third day, all remaining plant material was removed and weighed. Consumption was computed by subtracting the amount of remaining plant material from the total amount presented to a mouse. Corrections were made for food weight changes caused by changes in water content. The body weight of each mouse was recorded at the beginning and end of a trial.

Dietary composition of mice in consumption trials was defined as the percentage (air-dry weight) which a food item contributed to the total weight of food items ingested. Food preferences were determined directly from dietary composition. Items were ranked in a preference order according to the proportion which each contributed to the diet. Since some of every item remained at the end of each 24-hr period in the consumption trials, all food types were available *ad libitum*; hence the use of dietary composition to determine food preferences was valid in this situation. Estimates of energetic intake were calculated from data on the caloric content of the plant parts (J. MacMahon, pers. comm.) and from the quantities of different plant parts ingested.

Table 1. Mean dietary composition of mice in consumption trials and mean frequencies of feeding on different plant foods by mice in observation trials

Plant species	Dietary composition (%)		Frequency of feeding (%)	
	Peromyscus maniculatus	*Perognathus parvus*	*Peromyscus maniculatus*	*Perognathus parvus*
Sitanion hystrix	77	78	89	88
Halogeton glomeratus	7	10	3	2
Chrysothamnus viscidiflorus	9	4	2	0
Descurainia pinnata	--	--	4	0
Atriplex confertifolia	5	5	1	3
Artemisia tridentata	2	3	1	7

Four deer mice and four pocket mice were used in the observation trials. The purpose of these trials was to provide an independent determination of feeding patterns. In each trial, a single mouse was placed for five days in one of two outdoor escape-proof arenas, each 2.5 m in diameter. Each arena contained entire plants transplanted in soil 20 cm deep and two nest cans with nesting material; no water was provided. Mature potted plants (one sagebrush, one shadscale, one rabbitbrush, one clump of squirreltail grass, one group of four halogeton plants and one group of tansy mustard plants) were arranged in a circle 2 m in diameter. Tansy mustard plants were replaced by squirreltail grass during later trials (after 25 July), because seeds of the former had been cast and the plants were dry. Approximately 10 g of squirreltail grass seeds were placed under a wire basket in the center of each arena; the basket prevented seeds from blowing but did not hinder access. Grass seeds were replenished daily.

The location and activity of a mouse were recorded every 10 sec for periods of 10-150 min between sunset and midnight. Mice were observed through a model 221 Javelin night viewing device with a 75 mm, f 1:1.4 lens. A 25-watt red lamp suspended 2 m above the arenas was required to provide adequate light. The data analyzed and presented here include only observations of food-related activities as described by McCabe and Blanchard (1950) and by Eisenberg (1963).

The quantity of plant food available to deer mice and pocket mice on the Curlew Valley site during the study period was assumed to equal the estimated seed reserves in the surface 4.7 cm of soil and the estimated annual net production of different plant parts. These estimates were based upon a study of shadscale in Curlew Valley (Gastó 1969) and upon Desert Biome data collected in Curlew Valley from 1967-1975 (Goodall et al. 1972; Balph et al. 1974; Klikoff and Freeman 1974; Shinn et al. 1975; M. Merritt pers. comm., R. Shinn pers. comm.). Estimates of plant consumption by deer mice and pocket mice on the Curlew Valley site were based upon estimated population densities of these rodents in Curlew Valley (Shinn et al. 1975) and upon results from the consumption trials.

RESULTS

Plant Diet and Preference

Only data from mice that survived an entire trial were included in analyses of dietary composition and frequency of feeding (Table 1). The surviving animals included two deer mice and 10 pocket mice in the consumption trials and three deer mice and four pocket mice in the observation trials. Although there is some question as to whether results from the two deer mice in consumption trials were representative, final impact estimates for this species were sufficiently robust to make unimportant the possible error produced by small sample size (see below), hence our decision to include these data in the present report.

Analysis of variance of the amounts of different plants consumed by the 10 pocket mice indicated that the mice ate different plant items in significantly different quantities ($P < 0.001$). Tests of least significant differences indicated that ingestion of squirreltail grass seeds was greater than ingestion of halogeton, which in turn was greater than ingestion of little rabbitbrush, shadscale and big sagebrush ($LSD_{.95,45} = 88$ mg). Analysis of variance of consumption of different plants by pocket mice differing in age or sex showed that selection of plant items did not differ between adults and subadults ($P > 0.5$) or between males and females ($P > 0.5$). Deer mice, like pocket mice, consumed greater amounts of squirreltail grass seeds than of other plant foods, although a meaningful statistical analysis of consumption trial results was not possible for deer mice because of the small size of the sample.

Observation trials yielded results similar to those of consumption trials. Chi-square tests indicated that the mice did not feed with equal frequency on different plants in the arenas ($P < 0.001$ for each species). Mice of both species fed less frequently than expected on all plants except for squirreltail grass seeds. The duration of feeding visits ranged from 5 sec to 25 min; however, despite this high variability, the relative frequencies of visits remained valid indicators of feeding patterns and supported the results of consumption trials.

Ingestion Rates

Mean daily ingestion rates of plant material by deer mice and pocket mice in consumption trials were 1,770 and 2,014 mg/mouse, respectively. Subadult pocket mice ingested a significantly greater amount per unit of body weight than did adults (175 and 119 mg·g body weight^{-1}·day^{-1}, respectively; Student's t-test, $P < 0.01$). However, there was no significant difference between subadult and adult pocket mice in the total amount of plant food ingested daily (Student's t-test, $P > 0.5$).

The average energetic intake of the captive deer mice was 7.31 kcal/day (Table 2), which was somewhat lower than caloric intakes cited by others for this species (10.36 kcal/day averaged over the entire year, Turner 1970; 8.97 kcal/day averaged over the entire year, Chew and Chew 1970;

Table 2. Caloric content of plant food items and estimated caloric intake by mice in consumption trials

Plant species and part	Caloric content (kcal/g)	Caloric content used to estimate intake (kcal/g)	Caloric intake (kcal/day)	
			Peromyscus maniculatus	*Perognathus parvus*
Sitanion hystrix				
Seed	4.079	4.079	5.59	6.38
Halogeton glomeratus				
Leaf	2.092			
Stem	2.939	3.328	0.38	0.73
Seed	3.097			
Seed-fruit	5.185			
Chrysothamnus viscidiflorus				
Flower	5.011	5.011	0.80	0.38
Atriplex confertifolia				
Leaf	4.160			
Seed	5.032	4.171	0.40	0.43
Seed-fruit	3.322			
Artemisia tridentata				
Leaf	5.150			
Herbaceous stem	4.733	4.967	0.14	0.26
Flower	5.017			
TOTAL			7.31	8.18

13.77-14.86 kcal/day averaged over the entire year, Schreiber and Johnson 1972; 11.95-15.05 kcal/day averaged over the summer months, Schreiber 1973). The mean energetic intake of the pocket mice was 8.18 kcal/day (Table 2), which agrees with estimates by others (8.47-10.78 kcal/day averaged over the entire year, Turner 1970; 6.35-8.38 kcal/day averaged over the summer months, Schreiber and Johnson 1972; 10.8 kcal/day under laboratory conditions, French et al. 1974).

Estimated Impact of Consumption upon Plant Community

To estimate the amounts of different plant items consumed by deer mice and pocket mice on the Curlew Valley site during the period of this study, we made the following assumptions: 1) that deer mouse and pocket mouse population densities were at a peak (3.8/ha and 9.5/ha, respectively; Shinn et al. 1975); 2) that major plant foods available to mice on the site were as presented in Table 3; and 3) that food preferences and feeding rates of mice on the site for the plants tested were similar to results obtained in the experiments. Deer mice and pocket mice consumed an estimated 6% or less of the parts of dominant plant species in the Curlew Valley study area during the summer and early fall (Table 3). The rodents' calculated impact was greatest upon seeds or fruits of squirreltail grass (a perennial bunchgrass) and halogeton (an annual forb). Their use of shrubs—little rabbitbrush, shadscale and big sagebrush—was negligible. At lower population densities (to as low as 0.9/ha and 0.5/ha for deer mice and pocket mice, respectively; Shinn et al. 1975), mice would remove even smaller quantities of plant items than the estimates in Table 3 indicate.

DISCUSSION

At least three major factors associated with the experiments could bias our attempt to relate the experimental trials to field conditions: 1) the stress of captivity, 2) reduced availability of arthropods in captivity and 3) differences in plant food accessibility in captive and natural habitats. These possible sources of error necessitate caution in interpreting our findings.

Table 3. Estimates of consumption by deer mice and pocket mice of plant parts in a shrub-bunchgrass community from 1 July to 1 October

Plant species and part	Plant food available to mice (kg/ha)	Plant food consumed by mice (kg/ha)[1]	Percentage of available food consumed
Sitanion hystrix			
Net annual seed production and soil seed reserves	32	1.85	6
Halogeton glomeratus			
Net annual fruit production	5	0.23	5
Net annual aboveground production	70	0.23	<1
Chrysothamnus viscidiflorus			
Net annual flower production	43	0.12	<1
Atriplex confertifolia			
Soil seed reserves	84	0.12	<1
Net annual seed production	6	0.12	2
Net annual seed + leaf production	378	0.12	<1
Artemisia tridentata			
Net annual flower + leaf production	246	0.06	<1

[1]The total amount of each item consumed by the mouse populations was calculated as follows:

$$A_i = \sum_p N_p I_{ip} t$$

where A_i is the total amount consumed of plant item i (kg/ha), N_p is the density (N/ha) of rodent species p (3.8/ha for deer mice and 9.5/ha for pocket mice), I_{ip} is the mean ingestion rate of plant item i by rodent species p (kg/day) and t is the duration of the study (92 days).

The strangeness and constraints of captivity probably were factors contributing to some of the deaths and to weight losses ($\overline{X} = 17.7 \pm 7\%$ of body weight) in mice. Increased metabolism and decreased food consumption may have caused the loss of weight. However, it is unlikely that conditions of captivity changed markedly the preference of mice for the food items presented.

Captive mice probably could find few or no arthropods to eat. Although mouse diets in natural habitats consist primarily of vegetation, a number of workers have found that mice eat substantial quantities of arthropods. In arid shrub communities, deer mouse diets consist of 40-69% seeds and fruits, 7-20% green vegetation, 21-36% arthropods and 5-12% other material (Jameson 1952; Williams 1959; Johnson 1961; Kritzman 1974). Pocket mice consume 33-80% seeds and fruits, 25-40% green vegetation and 3-25% arthropods (Johnson 1961; Iverson 1967; Franz et al. 1973; French et al. 1974; Kritzman 1974). In the present study, mice may have eaten more plant material in captivity than in Curlew Valley to compensate for the assumed reduced availability of animal material; however, all of the mice lost weight in captivity. The degree to which these opposing influences compensated for each other is difficult to assess.

The captive mice had ready access to surplus quantities of each of the food items presented. This may not have been the case for mice on the Curlew Valley site, even though the plant species (except perhaps for little rabbitbrush and halogeton)

were commonly available. The energetic cost of obtaining each food item, as well as the animals' perception of food choice, probably differed between field and captive situations.

Results of both the consumption and observation trials indicated that mice were selective in what they ate. Big sagebrush flowers and leaves formed a very small part (2-3%) of the experimental diets of deer mice and pocket mice, as Williams (1959) and Johnson (1961) found in sagebrush communities similar to that of Curlew Valley. Sagebrush comprised 57% of the estimated aboveground plant biomass and 29% of the estimated plant food resource on the Curlew Valley site. Its flower parts and stem tips were within reach of deer mice and pocket mice, and captive deer mice occasionally climbed into the sagebrush canopy. Caloric content (Table 2) and water content (23% of fresh plant material by weight) were sufficient to be of benefit to the animals. On these bases, one would expect a substantial proportion of the diet to be composed of sagebrush. The presence of digestion-reducing compounds in the plants is a plausible explanation for the rodents' failure to eat sagebrush. Deer mice and pocket mice, as "generalist" consumers, would not be expected to possess detoxification mechanisms against such compounds (Rhoades and Cates 1976).

Shadscale seeds and leaves comprised 5% of deer mouse and pocket mouse diets in the present study. Similarly, Johnson (1961) found that 4-29% of the stomachs of deer mice trapped in sagebrush and shadscale stands contained shadscale seeds and leaves. On the basis of availability in Curlew Valley (35% of aboveground plant biomass, 54% of plant food resource), caloric content (Table 2) and water content (44%), one might expect shadscale to constitute a sizable proportion of the diets of deer mice and pocket mice. Some factors which might have been responsible for the low ingestion levels observed were scarcity of seeds within fruits of this plant (only 12-25% of shadscale fruits contain seeds; Gastó 1969), hardness of seed shells, small seed size (1.28 mg) and high salt content of leaves. Great Basin kangaroo rats (*Dipodomys microps*), which eat large quantities of shadscale leaves, are known to strip away portions of the leaves which contain high sodium concentrations (Kenagy 1972); however, we observed no such behavior in either deer mice or pocket mice.

Little rabbitbrush comprised only 9% and 4% of the respective diets of deer mice and pocket mice in the present study, despite its relatively high caloric content (Table 2) and adequate water content (28%). Mice may encounter rabbitbrush only infrequently on the Curlew Valley site due to its relatively low abundance (3% of aboveground plant biomass, 5% of plant food resource) and its patchy distribution. Lack of familiarity might have been a factor reducing consumption of this plant by the captive rodents.

Halogeton formed 7% and 10% of deer mouse and pocket mouse diets, respectively. Although its relatively high water content (57%) rendered it a potential source of water, the presence of oxalate, a known toxin (Kingsbury 1964), might have limited the rodents' consumption of halogeton. Johnson (1961) found no halogeton in the cheek pouches of pocket mice, although he did note a high incidence of seeds and leaves of this plant in the stomachs of deer mice. The rodents in our study may have been unfamiliar with halogeton, as it was low in abundance (2% of aboveground plant biomass, 8% of plant food resource) and patchily distributed on the Curlew Valley site.

Seeds of squirreltail grass formed 77-78% of the rodents' diets in the present study, although the grass formed only 3% of the Curlew Valley community's estimated aboveground plant biomass and 4% of the estimated plant food resource. This finding agrees generally with those of other workers. Cheatgrass (*Bromus tectorum*) and crested wheatgrass (*Agropyron cristatum*) frequently were found in the stomachs of both rodent species in southern Idaho (Johnson 1961). Pocket mice were found to rely heavily upon ripe grass seeds (Kritzman 1974). The seeds of squirreltail grass are relatively large (2.5 mg) and do not require removal of a thick seed coat to determine whether or not a seed is present. Caloric content (Table 2) is similar to that of other plants, although moisture content is low (1%). Thus, the factors most probably responsible for high consumption of grass seeds were large seed size, ease of detection and ease of husking.

Our study suggests that deer mice and Great Basin pocket mice did not limit plant production on the Curlew Valley southern shrub Validation Site. However, these species accounted for only about 50% of the site's estimated rodent biomass; other common species included least chipmunks (*Eutamias minimus*) and Great Basin kangaroo rats (Balph et al. 1974), which eat seeds and leaves of grasses, halogeton and shadscale (Johnson 1961; Kenagy 1972). Perhaps in a year of high rodent density and low seed production, the animals might remove a majority of the grass seeds on the Curlew Valley site. However, even under such conditions, seed predation by rodents may have less of an impact upon the plants than one might expect. Soholt (1973) estimated that even the removal of 95% of one plant's seed crop in the Mohave Desert by Merriam kangaroo rats (*Dipodomys merriami*) would reduce the plant's population by only 30%. Wilcott (1973) composed a model describing desert annual seed populations, of which one component was the rate of seed loss through predation. He demonstrated that high rates of seed loss (80-90%) from the current crop will not result in extinction of the annuals if the loss of older seeds is not too high (generally below 50%). Chew and Chew (1970:17) suggested that high rates of seed removal may actually "...increase the productivity of existing plants by reducing competition among them." Activities of rodents other than ingestion (such as burrowing, caching of seeds, surface digging during foraging and removal of or damage to portions of plants which are not consumed) may have a greater effect than ingestion upon plant composition and distribution (reviewed by Harper 1969; Janzen 1971; Golley 1973; Chew 1974).

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